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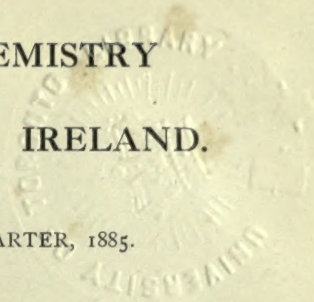
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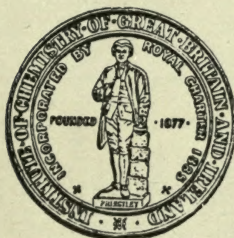
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LECTURES
ON
**The Research Chemist in the
Works, with Special Reference
to the Textile Industry.**

By
W. P. DREAPER
(Fellow of the Institute).

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30, BLOOMSBURY SQUARE, LONDON, W.C.
1914.

The Lectures were delivered before the Institute of Chemistry, at the Imperial College of Science and Technology, South Kensington, London, S.W., on 29th October, 1913, Prof. R. Meldola, F.R.S., President, in the chair, and on the 26th November, 1913, Dr. George McGowan, Vice-President, in the chair.

SYLLABUS OF LECTURES.

The British Textile Industry. Nature of training required for textile research. Conditions which govern investigation. Interpretation of results. Time and cost factors. Secret working. Improvements in plant and manufacturing operations. Originality an essential factor. Influence of local conditions on industry.

Works research laboratory. Establishing experimental works. Nature of investigation. Study of detail a key to success. Mercerising and Schreinerling. Value of observation. The chemist and the workman.

Technology of textile fibres.—Methods of manufacturing artificially prepared yarns and fabrics. Their value in commerce. Introduction of new fibres. Variations in raw materials.

Influence of theory. Is the action of dyeing, physical, electrical, or chemical? Chemical constitution and physical properties of fibres. "Neutral salt" reactions in presence of fibres, etc.

Bleaching, dyeing, printing and finishing operations. New dye-stuffs and their application. Silk weighting. Types of machinery used. Water supply.

Special processes.—Embossing, waterproofing and gas-proofing fabrics. "Cross dyeing" effects. Dyeing furs. Action of heat and moisture, etc.

The chemist and engineer. New processes and management of plant. Electro-bleaching. Electro-typing. Use of spray. Disposal of waste liquors.

Development of textile research, and its systematic treatment.

EXHIBITS.

The lectures were illustrated by exhibits of textile materials, etc., in intermediate and finished stages, more particularly :—

MERCERISED AND SCHREINERED MATERIALS.—Cotton cloth in intermediate stages between woven material and finished state, showing effect of singeing, bleaching, Mercerising, and Schreinerling. (Messrs. Naylor, Jennings & Co.)

ARTIFICIAL SILK.—Different makes.

WOOD PULP YARN and materials woven from same. (Krön Process.)

CELLULOSE FABRICS.—Made directly from cellulose solution. (Ratignier and Pervillac Process.)

FURS.—Dyed with *meta*-phenylenediamine, etc. (Lent by Mr. M. C. Lamb.)

PRINTING ON COTTON.—Turkey Red, in different stages. (Manchester Municipal School of Technology.)

DISCHARGE PRINTING ON SILK. (Messrs. Grout & Co., Ltd.)

BLOCK AND MACHINE PRINTING ON DIFFERENT MATERIALS.—Showing different styles in printing, including wax resist, discharge, multi-coloured prints in different intermediate stages and demonstration of block printing. (Swaisland Printing Works; Messrs. G. P. & J. Baker, Ltd.)

SPRAY PRINTING.—Demonstration of the Aerograph Process.

MANGANESE PERMUTIT.—Removing manganese salts from water. (Water Softeners, Ltd.)

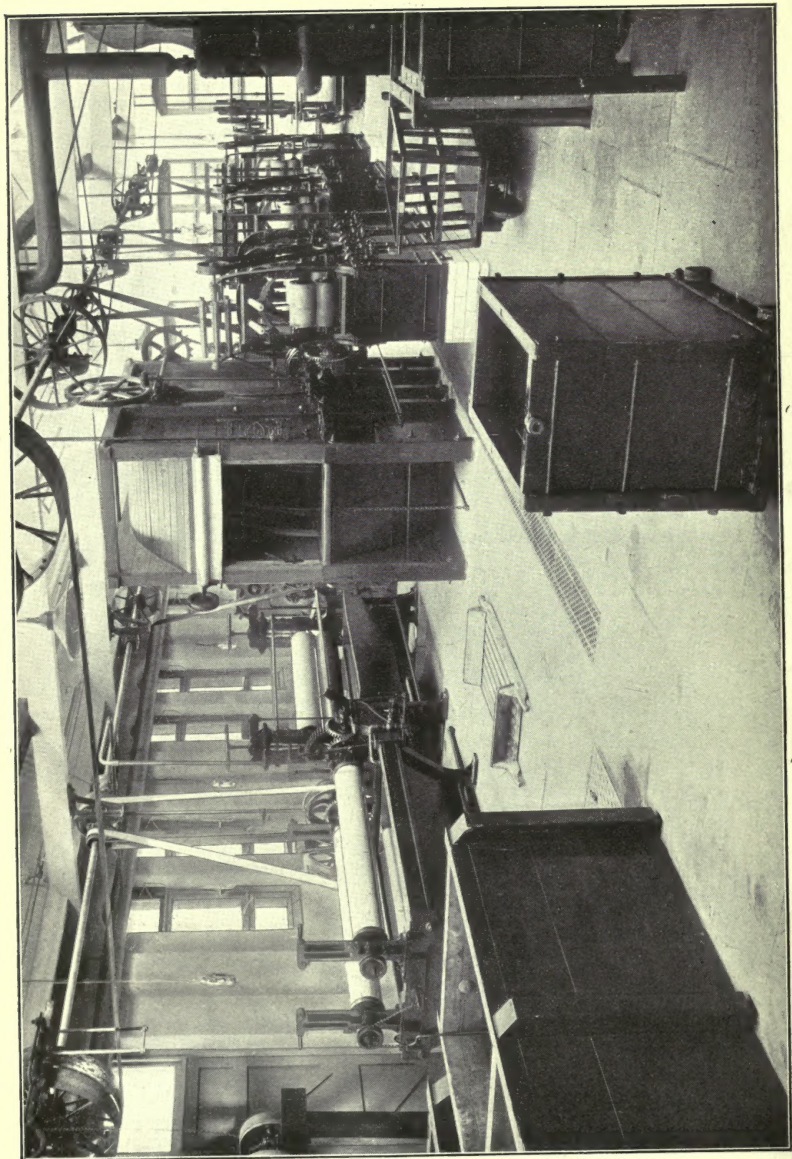


FIG. 1.—EXPERIMENTAL DYE-HOUSE (BRADFORD TECHNICAL COLLEGE).

The Research Chemist in the Works, with Special Reference to the Textile Industry.

THE subject under review is one which requires for its satisfactory treatment a knowledge of working conditions, which is certainly beyond that possessed by any one investigator. It is also difficult to express opinions on the value of procedure which will be accepted by all industrial chemists. For they, as a class, work under such different conditions and are naturally influenced by differences in temperament and past training. It will, therefore, be understood that, although any remarks made this evening are based upon a somewhat varied experience in works practice, this has been to a great extent connected with the treatment, or production of textile materials. This industry, however, is of so varied a nature that the principles involved are very similar to those met with in most old-established industries, and in many of more recent origin.

I hope to be able to suggest the conditions which surround the textile chemist, by indicating the nature of the methods employed in dealing with some of the problems which have been considered in the past. Although in many cases the work involved is of a general nature, I venture to suggest that the influence of a chemical training can always be traced in the method of attack. In respect of the training required by the industrial chemist one cannot do better than quote from Bacon, who considered that :—

“The strength of all sciences, which consisteth in their harmony, each supporting the other, is as the strength of the old man’s fagot in the band.”

Mr. C. F. Cross, in his lectures on “Cellulose,” gave particulars concerning the actual gross value (at factory cost) of certain of the vegetable fibres. The following table of particulars given from the First Census of Production (1907) will indicate the “total gross value” of textile materials or fabrics as manufactured.

THE TEXTILE INDUSTRY (1907) IN THE UNITED KINGDOM.

Trades.	Gross Output, Selling Value, or Value of Work Done.	Materials Used.	Persons Employed.	H.P. Utilised.
Cotton	174,601,000	128,697,000	572,062	1,229,212
Woollen and worsted trade	75,905,000	55,369,000	264,021	325,244
Jute, hemp, and linen	32,101,000	22,349,000	154,496	168,147
Silk	5,236,000	3,336,000	32,198	18,867
Lace	10,715,000	6,813,000	36,840	10,339
Bleaching, dyeing, and finishing	17,940,000	7,212,000	103,813	190,252
Flock and rag	1,776,000	1,445,000	6,385	2,594
Other trades	15,287,000	9,817,000	83,229	43,110
Total	£333,561,000	£235,038,000	1,253,044	1,987,765

Fuel Consumed (77 per cent. of firms, on average, made Returns):

Value	£ 8,137,274 coal.
„	45,125 coke.

It will be seen that the gross value amounts to the considerable total of £333,000,000; that materials to the value of £235,000,000 were used in their manufacture; and that 1,253,000 persons were employed in their manipulation. The power used amounted to 1,987,000 H.P. and 77 per cent. of the firms engaged in their work made a return that they had

used during the same period £8,137,000 worth of coal. These figures indicate that there must be under modern conditions an ever-increasing call for research chemists in this industry. If the standard that one chemist is required for every 2,000 persons employed in the textile industry were set up, there would be room for no less than 620 highly trained chemists, who would each be dealing with an "average gross output" of the value of over £500,000 per annum.

When it is remembered that a Continental combine in the aniline dye industry employs more than 600 chemists, the above estimate of ultimate requirements cannot be considered unreasonable. The effect of this army of chemists working in the interests of the textile industry would naturally lead to astonishing developments and to considerable improvements in detail.

The student who enters a works on the research side, after having received a University education (or having equivalent qualifications), will, undoubtedly, possess a knowledge of chemistry which will rank as an immediate asset. In a way, the college training will also have prepared him for actual working conditions by indicating their nature. It would serve no useful purpose on this occasion to discuss the relative value of the different methods utilised in some of our leading technical colleges with this object in view.

In addition to this knowledge of theory, the student will make immediate use of any experience he may have gained in ordinary analytical operations. His work in this direction will not be characterised by that accuracy and dispatch which comes to those who have devoted years to such operations, but the knowledge he possesses in this branch of chemistry will rapidly come into play for control purposes. Future work will, however, call for a special rather than a general experience in this direction. It will often be necessary

to devise new methods of analysis, or, at least, modify old ones, before they can be utilised in industrial investigation.

A knowledge of the principles which underlie such work is, therefore, a very necessary equipment for the young investigator. This also involves a training which has a special value to those entering this, and most other, industries.

In many cases, work will rest on the borderland of industrial research, where the actual analysis of certain products can replace actual experiment in very few cases. It is the latter which counts. The former is generally of secondary value.

On leaving college and entering a works, I found almost immediately that it was possible to correct certain analytical figures which had been supplied by a leading analyst. This simply meant that one of us was in the works, and the other outside. This prevented the interpretation of results in such a manner that certain substances were returned as present which had not been used in the manufacture of the material examined.

A recent case of a more general order may be quoted. A German tanning firm had doubts about the chestnut extract they were using, and sent samples to seven or eight of the leading analysts of tannin materials. Some of these confirmed the firm's opinion that a tannin substitute was present, while the others returned the extract as quite pure. The difficulties met with in analysis and recognition of certain organic substances was the cause of such differences being recorded (*Le Cuir*, May 1st, 1913).

The research chemist will probably enter the works at an early age. If he has finished his college course at twenty, a year or two of teaching work will do no harm. It will consolidate his knowledge of theory under the stress of imparting it to others. Better still, if it is possible to determine, at that stage, the direction of his future work, he may engage

in a post-graduate course of research. The actual time of coming in contact with works conditions should not be delayed beyond the age of twenty-two years, for the mind must be "plastic" and capable of readily adjusting itself to industrial conditions, which are naturally different from those surrounding the student in a college laboratory.

The introduction of a time factor in its relation to cost of production will alone have a great influence. Work in the factory may be practically continuous in its operation. A fresh set of men often enter at 6 p.m. to continue the work done by those they displace. The young chemist will, therefore, quickly realise that he has to deal with entirely new conditions. These will at once claim his interest by reason of their novelty and importance. He will soon be engaged in the attempt to control, or modify, operations proceeding on a scale possibly measured in tons, or thousands of yards.

The raw material will enter at one end of the factory. At the other end, it will leave in a more or less "finished" state. This operation may, in some cases, take months to complete, during which time the material may be subjected to innumerable processes which may possibly modify both its physical and chemical properties. The chemist will endeavour to understand, and so control, these operations that, during transit through the works, the material may receive a minimum of treatment to produce a maximum effect; for this generally means satisfactory working conditions, and low cost of production.

This will represent a considerable part of his work, which will have a way of extending itself in directions which could not possibly have been anticipated. The young chemist will naturally be prepared to meet such conditions—and welcome them.

What general effect can the successful investigator have on

the methods and processes employed in work of this nature? He must aim at a position under which determining methods of working are being constantly modified in detail; or even in nature. Under the most successful conditions he may, in time, find himself working three years in advance of those who are not taking full advantage of modern methods of investigation. It is difficult for an industrial chemist to hide from his experienced rivals a process or method which can be detected in the finished product by ordinary, or even special, means. Many improvements are, however, of such a nature that they cannot be detected in this way, and then the above condition may be found to apply. In most cases this standard is a reasonable one to aim at. More than this can hardly be expected, unless the Patent Law comes in to protect ideas and methods for a longer period. When this is realised, there is obviously no finality to work of this nature, and as a result a condition of continual change will probably be set up in the factory.

It is surprising to what an extent secret working has in some cases secured a monopoly. Especially is this so, when the effect of a process, or use of a machine is not self-evident or easily traced in the finished article. Under such conditions, and more particularly where an industry has not adopted a scientific control, a certain sequence of operations has been known to remain the monopoly of a firm, or a limited number of firms, over many years,—as witness the Turkey Red industry.

Even where a close examination of the finished product might suggest, to the experienced investigator, the method of treatment employed, its presence is often overlooked or unsuspected because of difficulties in the way of identification or analysis. A slight and inexpensive change in manufacture may add ten per cent. to the apparent value of a textile material. What this means on a large output can easily

be imagined, as the ordinary net profit on manufacture may be somewhere between twenty and thirty-five per cent.

The research chemist is, therefore, constantly trying to improve or devise methods of investigation which will enable him to keep in touch with the work of those who, for the time being, may be regarded as his competitors ; and the methods utilised to this end are based more often upon personal experience than published results. Such processes generally deal with the recognition of certain physical or chemical changes which occur when the material is subjected to tests corresponding to those in actual practice. Owing to their value to the investigator, such methods are not generally disclosed. Work in this direction, or modifications in accepted processes of analysis, and in the proper interpretation of results, are often carefully guarded, until through some change in procedure, they no longer retain their original value. Many such examples will occur to the technical chemist.

The aim of the chemist in this respect is to obtain some clue of a physical or chemical nature which will suggest to the experienced investigator the nature of superior working methods. Such methods of obtaining an insight into hitherto unknown processes or applications are of considerable value. They can only be successfully used by the investigator who has a practical knowledge of manufacture in addition to an ordinary laboratory experience. Thus, to the industrial research chemist, analysis may have a different meaning to what it has to the general consulting chemist. It is a means to an end which possibly may be the discovery of the nature of a process. Analysis is also utilised to obtain the correct working conditions of a new process, or the better control of an old one. It will be gathered from these remarks that procedure must in many cases be empirical in its nature.

At the dinner of the Institute of Chemistry, held in 1911, one of the speakers—a Lord Justice of wide experience in

scientific matters—claimed that under modern conditions was often necessary to “set a chemist to catch a chemist.” This statement is true in its application to industrial research, and the industrial chemist does not neglect this particular side of his work, and so far as possible translates it into actual experience.

Methods adopted in the more general work of improving existing processes are of first importance. They cannot be dealt with in any detail on the present occasion, although they play such an important *rôle* in the day's work. An attempt will, however, be made to indicate the nature of this branch of industrial research, by referring to examples which have occurred in actual practice.

The research chemist often has to watch ordinary manufacturing operations over extended periods before any plan of control or improvement can be devised. Light is sometimes thrown upon such a position by the occurrence of irregular results in the daily output, or a systematic examination of the effects produced by accidental, or pre-determined, variations in working conditions. Many problems have been successfully investigated by such means. Such variations, as they occur in everyday practice, may often lead to important improvements, or even suggest new processes. Thus, the research chemist will soon realise that his right place is in the works. He will use the laboratory mainly to follow up ideas in detail.

The introduction of new methods naturally calls for an immediate re-examination of the conditions of working of existing processes. This may often secure to them an extended lease of life, as in the case of the colloidon method of preparing artificial silk. In these days of costly apparatus or plant, this factor must not be lost sight of. It is the first point to consider when the chemist finds he has to deal with, and equal, the results obtained, by the introduction of a more efficient

process, leading to the production of a better or cheaper product.

The successful worker must, however, go further than this. Experience indicates that important results have generally been obtained by striking out boldly in a new direction. The risk connected with such pioneer work can always be minimised by working on a moderate scale, and making sure of the details of every step as it occurs in a natural sequence. With long experience, it is sometimes possible to experiment at once on a large scale with a reasonable chance of success, but this course should never be followed by the beginner. Such conditions are comparatively rare, and generally governed by some secondary consideration, such as the prohibitive cost of new apparatus, as compared with the utilisation of that already available in the works.

In industrial research, it is sometimes more important to know what not to do than the reverse. This restraining influence must be developed equally with originality. In this, the worker will naturally be guided by instinct, which may be defined as the tempering of past experience by an untiring caution.

The work of the industrial research chemist can generally be classified under the following headings :—

- (1) Analysis, as a direct aid to research.
- (2) Investigation of the general conditions of working in the industry elsewhere.
- (3) Application of new processes and inventions to the needs of the factory.
- (4) Original investigation.

The last two are concerned with improvements in existing processes, or their substitution by more efficient ones ; the working out of new methods which will tend to economic development ; or the manufacture of new products. In a works of any standing, such a programme is sufficiently wide

in its character to offer an attractive field to several trained investigators.

Once more, the young chemist may be urged to spend most of his time in the works, only working in the laboratory when some work requires systematic investigation. Many manufacturers have objected to this procedure in the past, but with tact, such opposition, where it still exists, can generally be overcome. The industrial chemist who remains in his laboratory will be hopelessly left behind in the race for progress.

It is impossible to say how far the chemist should experiment in the laboratory, or when he must carry out the necessary investigation in the works itself. In the latter case, it is well to leave such labour as does not entail exact measurement in the hands of the workman. The chemist must, however, *know how to carry on such work*, and in cases of difficulty, be able to do so under the eyes of the workman. This is sometimes a rather trying experience to the novice, but it must be faced.

If this section of the chemist's work is not covered, those who attend to such matters will one day "give him a warm time" in the world's markets. Thus, the labour of the chemist is regarded by the manufacturer as a necessary assurance against undue competition.

The Laboratory.—This must be of sufficient area to enable experimental work to be conducted on a small scale. It should have, in addition to the ordinary bench fittings, power, electric current, steam and, if possible, compressed air, laid on. So far as my experience goes, power up to 5 to 10 H.P. may be required. Beyond that amount, experimental work is better conducted either in a shut-up part of the factory, or if this is unnecessary, in the works itself.

If electrical power of low or varying voltage is required for furnace or electro-chemical operations, it is as well to run a small dynamo in the laboratory itself. If electric

power is wanted continuously, either the town supply can be tapped to run a dynamo-motor set, or else a small 10 H.P. gas engine can be utilised. I have run an experimental plant continuously for several months, with a gas engine (running on town gas and fitted with special lubricating arrangements) without any personal attention at night. This can be done under modern conditions, but if steam is continually available, that system is, on the whole, a more satisfactory one. The gas plant will, however, work well if reasonable care be taken.

Where it is impossible to work on a laboratory scale, and full-sized plant must be utilised, the output is naturally kept down to the lowest limit. This stage is a trying one, especially to the young investigator; for it is almost inevitable that new difficulties will continually crop up. Those of a serious nature must be overcome as they occur, or the work abandoned.

A dark room is practically an indispensable adjunct to the laboratory. There is hardly an industry which can be critically dealt with without the aid of a camera used in conjunction with the microscope. In the case of dye-works, special model dyeing, printing, or other apparatus will be required similar to that found in the modern technical colleges devoted to the subject.

Where a process or manufacture has to be considered or attempted under new local conditions, with the object of conducting it on a large scale, there is only one way of working which will assure success. Experimental works should be set up; working with the smallest possible plant which will allow for operations being conducted on a working scale. Only in this way can a fair estimate of working costs be arrived at, or (in the case of a new product) market conditions gauged. These factors are the *crux* of all commercial operations. Working costs are nearly always under-estimated; but, more important still, new conditions and requirements constantly come to the surface, when a process is being set

up on a commercial basis. With the best intentions, it is necessary to display extreme caution in this extension work.

In some cases, where experimental works have been erected, it has been observed in the light of subsequent experience, that these have been erected on an unnecessary scale. Mistakes in this direction cannot be rectified without an expenditure of considerable sums of money, which would have been employed more profitably in the ultimate extension of plant.

The cost in time alone absorbed in any change in apparatus or plant (and such may be considered inevitable) will be correspondingly reduced. Each case must naturally be considered on its merits. Probably the most extensive experimental works on record were those erected in Norway by the Berkeland-Eyde group to demonstrate their process of fixing nitrogen from the air. 10,000 H.P. was actually utilised in this experiment. This has been followed by the erection of works which will utilise 250,000 H.P. and produce 150,000 tons of artificial nitrates per annum.

Be bold, but careful, when starting experimental works, and reasonably certain that all data which can be obtained on a laboratory scale are already secured. Only then, should the establishment of experimental works be attempted. Much can be done in the way of experimental plant, etc., in the laboratory with £100. An experimental works will probably absorb anything between £3,000 to £10,000 before any important results or improvements can be obtained.

The work of the chemist in an ordinary textile works may be concerned with—

- (a) Examination of raw materials, and the utilisation of physical or chemical methods for estimating their value.
- (b) Preliminary treatment of raw materials.
- (c) Conditions of working the same into yarn.

- (d) Treatment received by yarns during manufacture.
- (e) Weaving conditions, and their influence on textile fibres.
- (f) Storing goods in the "grey."
- (g) Bleaching, preparing, mercerising, dyeing, printing, embossing, etc.
- (h) Defects due to "finishing" processes.
- (i) Defects due to subsequent storing.
- (j) Analysis of textile materials.

This list is not exhaustive, but it includes industrial operations which must be regarded from a chemical point of view, in order that the influence of processes upon materials (so far as physical and chemical changes are concerned) may be realised and controlled. Such investigation may be chemical, physical, or bacteriological in its nature—often all three.

It sometimes happens that preliminary operations of a seemingly innocent nature induce material changes which cause endless difficulties in subsequent treatment. These disturbing causes will be entirely overlooked if the chemist does not carry his investigations back to the raw material and examine processes on the broadest lines.

It is a feature of modern industry that new methods are utilised very rapidly. An industry may be suddenly revolutionised. An example of this may be seen in recent changes in the manufacture of incandescent lamp filaments, which have rapidly replaced the older methods of preparing carbon filaments. These were originally produced by carbonising a cellulose thread made by the zinc chloride method; and now by processes concerned with the manufacture of metal filaments. Changes of this order necessitate a complete re-organisation of plant and methods of production. They are often met with in the textile industry.

To illustrate this point, two cases may be cited which deserve special attention, on account of the way certain essential factors have controlled their commercial use.

The cotton industry has of late years been greatly influenced by two inventions. Both were brought to the commercial stage by following up earlier work in greater detail. These processes are known respectively as "Mercerising" and "Schreinerling." Each may materially increase the value of a cotton yarn or fabric by causing it to resemble silk, wool, or even linen in appearance.

It is hardly necessary to inform the chemist that, in the process of mercerising, cotton is subjected to the action of a caustic soda solution. Certain effects produced by this treatment were first noticed in the year 1844 by Mercer. The cotton was modified in certain of its qualities so that its use became important in certain minor directions; but the fibre was not materially changed in appearance. For years this process was only used to a limited extent, for the essential factor—which was to create such a revolution in textile practice—remained unrecognised. Forty-five years passed before Lowe in 1889 filed a patent for improvements in mercerising. In this document, the essential factor was actually mentioned. Still there was no application. The patent was actually abandoned!

In the year 1895 Thomas and Provost secured a patent (since recognised as involving the same principle as that mentioned in Lowe's specification), and mercerised yarn, as it is now known, made its appearance on the market. So superior looking is this product, that an ordinary individual might well mistake it for spun silk. This treatment of cotton has developed to such an extent that it is considered by many to be largely responsible for recent progress in our textile industry.

The point to be considered is, that the essential factor to success, which is partly chemical, partly physical, was not recognised industrially for many years after it had been suggested in a patent specification. It was not realised that

the fibre must be kept under a condition of strain during at least one part of the process ; or that a long staple cotton (Egyptian) must be used if the treatment is to have its

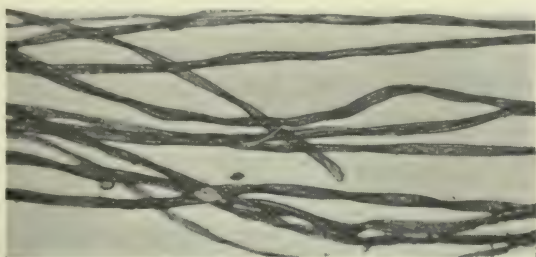


FIG. 2.—COTTON FIBRES ($\times 100$).

maximum effect. The mere chemical operation of mercerising was, in itself, ineffective. (Figs. 2 and 3.)

Thus, it is evident that the modern chemist must be prepared

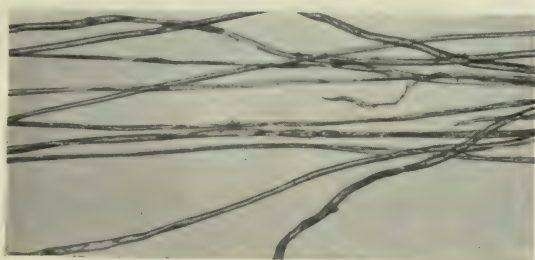


FIG. 3.—COTTON FIBRES AFTER MERCERISING UNDER TENSION ($\times 100$).

to carry his investigation to the extreme limits of experiment, or satisfactory results will not be obtained. Also that he must extend his work beyond the realm of chemistry proper. A more general knowledge and scheme of working are necessary

if the laboratory is not to remain a mere adjunct to the engineering department. The term "chemical technologist" is one which possibly best describes the qualifications of the industrial investigator, and the knowledge he must possess.

Practical experience generally indicates that what we might call "college chemistry" will not, in itself, carry one very far under modern conditions. The research man must possess a working knowledge of general physics, and also the power—



FIG. 4.—MODERN MERCERISING PLANT
(MATHER AND PLATT SYSTEM).

within limits—to apply such knowledge when working under industrial conditions.

There are many other problems connected with the actual processes of mercerising as it is worked to-day (Fig. 4), which concern the chemist; the recovery of spent caustic soda lye is one, and on this the economic success of the process to a great extent depends. In this operation, vacuum evaporation plays an important part. (A typical apparatus for this purpose is seen in Fig. 5.)

In the second case, that of Schreinerling, the same argument

holds good but in a more general way. Dr. Schreiner has stated that his original experiments were based on an attempt to copy in metal the surface of a silk fabric, and then to impress this on to the surface of a cotton fabric. It was thought that, by such means, cotton might be made to take the appearance of silk.

Although the first results obtained were not very satisfactory, they suggested further experiments, which resulted in the ultimate production of the well-known "Schreiner finish." Parallel lines were engraved on a steel roll, and



FIG. 5.—CAUSTIC SODA VACUUM RECOVERY PLANT
AS USED IN MERCERISING (SCOTT SYSTEM).

under suitable conditions of temperature and pressure brought in contact with the surface of a mercerised cotton cloth. This further step was inevitable in the hands of a trained investigator. The effect produced was such that the process has now a world-wide application.

In both these cases previous investigation had been undertaken, but not carried to its natural limit. In the latter case, experiments had been also undertaken in England, but apparently abandoned. They were, however, sufficiently definite to subsequently upset the Schreiner patent in this

country. To emphasise still further the importance of general knowledge it is interesting to note that Schreiner was a chemist as well as an engineer. He succeeded by applying his dual knowledge to the correct solution of the problem. In its modern developments, and more particularly in the so-called "permanent finish," the process of Schreiner is best worked by those who have a knowledge of the action of high temperature on the surface of a more or less hydrated cellulose fabric. This may not sound very complicated, but it means a good deal in practice, and entails a great deal of experimental work.

When the student considers these processes, he will realise that the difficulties and nature of modern industrial research are closely concerned with detail. This is always so. Many problems of similar importance undoubtedly still exist in the textile industry, but these will be solved only by the trained investigator who attends to this essential point.

If either of these patented processes had been upheld in the English Courts, our cotton industry would have paid heavy tribute to these inventors, who, first and last, studied detail to an extent which secured ultimate success.

Thus, success is often closely associated with the art of carrying existing processes a stage further. It is with the careful working out of additional detail that it is associated.

In numberless cases, progress is only secured by following up a seemingly unimportant point. This being so, the importance of a training, be it self-inflicted or otherwise, which qualifies a man to deal with such problems is evident. In its absence, progress can only be realised by the more slowly working aid of rule-of-thumb.

The presence of this factor has given the rule-of-thumb man great power in the past, for he has at his command a wonderfully accurate instrument in the trained eye. The chemist with all his apparatus is in some cases no match for him. Only by

studying his methods, and subjecting them to systematic investigation, will some point be disclosed which the worker had not fully realised. This often represents the chemist's best way of improving methods already in use.

In certain casting and metal operations, it is known that "the practical man" still holds his own against a system of temperature measurement, based upon the most accurate means of registration available. Trained from the age of twelve to fourteen in the ways of a particular process, his familiarity with certain effects, and everyday experience is such, that he carries on operations with a degree of accuracy and caution which it is difficult to equal, much less surpass, by any of the so-called exact methods. Such conditions still apply in many cases in the textile industry. Let the young chemist always remember this. It may save him from many an awkward position.

The investigator, sooner or later, realises the essential value of empirical methods, and if he is wise lets the worker know that he does so. In this way, the chemist gains the worker's confidence, and the latter more clearly realises the true aim of research. Once this position is established, the workman will naturally draw attention to any variations in working which may occur, or make suggestions of distinct value. The workman has a great advantage. His mind is continuously concentrated on one operation. Thus, it often happens that only by a careful study of deviations from the normal will the research chemist be able to report progress. His aim is to explain and control, the workman's to manipulate.

Facts which are but "curiosities" to the workman, and have remained so for many years in some cases, must be carefully investigated in detail by the chemist. They often represent the starting point for improvement—a first aid to progress, when all other means have failed. Time given to such investigation is never lost, for experience in the

ways of processes is a commanding asset to the industrial chemist.

The young investigator will constantly meet with variations in products apparently produced under identical conditions. This is calculated to bring him to his senses as quickly as anything. To deal immediately with such a position he must naturally have a very definite fund of experience to draw upon. In many such cases the "man-about-the-works" will, for this reason, come sailing in miles ahead of him. In this event, the young chemist must always look as if he likes it—and start on the next step in his programme. He will win in the long run.

It is the duty of the investigator to discover those workmen who control operations of vital importance, to study their ways, and to get upon such terms with them, that they will come to him for information; to study their methods in the light of every particle of knowledge he possesses, and if possible to improve on them. Incidentally, this is a sure way to command the respect of the worker—and achievement in this direction may safely be regarded as a distinct sign of progress. It must always be remembered that laboratory practice has in the long run to be translated into factory procedure, and the transition stage will be greatly aided by conditions of mutual trust which are established in some such way.

Looking back over past experience it will be realised that radical improvements have had their origin in the study of a defect, or an occasional superlative result as it occurs in the day's work, and that, in the first case, this has often been noticed by some foreman or workman.

An example of this comes to mind where a long-wished-for improvement was observed to occur accidentally in the case of a single piece of cloth. After a long chase, the cause was tracked to its origin. When recognised, the method by which this effect was produced was applied by a suitable mechanical

device to the whole output. One uses the term "accidental" as it applies to what originally happened, not to the systematic observation which alone suggested its importance and ultimately brought it within range of everyday experience. Entirely different mechanical conditions to those originally observed were necessary to make certain that the "accident" would always occur. This entailed the working out of new machinery. The process is still a secret one, so nothing can be said about actual procedure. It is one of those operations where the clue to its detection is lost in the subsequent stages of manufacture.

Where operations are conducted on a large scale, there is a greater chance of recognising such conditions. An improvement when applied on a larger scale has also a greater value. It is, therefore, better for the young chemist to get into a large works; unless he is compelled to enter a single department, in which case the greater freedom in a small works may be more valuable in spite of restricted output.

On the Continent, young chemists or chemical engineers often migrate from one works to another. Such action is even said to be encouraged, it being considered beneficial to the chemical industry as a whole. Under English conditions there is a strong tendency for a man to remain in a works for a number of years. Both systems have advantages, and have obviously grown up to satisfy local conditions.

Passing on to review the present position of the technology of textile fibres, the lines upon which progress is being achieved in industrial research will be considered.

Leaving, for the time, the natural fibres and their complicated treatment, the attempts made to supplement or even replace these products by artificially prepared ones may be noticed. This at once brings us into contact with investigation where results depend upon a knowledge of engineering as well as chemistry.

First of all the attempts to manufacture certain fibres directly from wood-pulp will be considered. In Krön's process, the pulp is spread on the machine in the usual way, and as it advances, is subjected over its width to the action of a number of water jets which are set at equal distances and directed against it. The streams of water "ridge" or nearly divide the wet pulp into equal sections, which are subsequently separated from one another and twisted into yarn.

The actual process calls for considerable attention to detail. The resulting yarns are even in substance, and may be woven into a variety of materials, such as table-cloths, sacking, carpets, etc., with surprisingly good effect.

In estimating the commercial value of such materials, it must be remembered that figures representing "breaking strain" and "elongation" (such as are used to record values for textile threads) may lead to erroneous conclusions. On such a basis the commercial value of these yarns is certainly under-estimated. This is instructive, for similar results will constantly be met with in practice. It always indicates that important factors have not been realised or covered by the test employed.

When these yarns have once been woven into a fabric, and occupy their place in, say, matting or wall covering, it is observed in practice that the life of the material may be greatly in excess of what would be expected from the breaking strain test. As a matter of fact, the wear of such a material is largely governed by the surface condition of the yarn. If the substance, even if it is wood-pulp, holds together and resists the action of any "rubbing" it may receive, it will have a considerably longer life than might reasonably be expected.

This process, which is one of several, sufficiently indicates the work which has already been done in the direction of producing yarns direct from wood-pulp. The problems involved call for the close co-operation of the chemist and

engineer. Conditions of manufacture at first follow those of paper-making, and introduce most of the difficulties connected with its manufacture. Those subsequently met with are peculiar to the operations involved. They are capable of more or less chemical treatment.

The second case is perhaps better known. The cellulose is first brought into a state of pseudo- or colloidal solution. Thus, the conditions of manufacture are entirely different. Solutions of cellulose are forced through minute orifices into coagulating media, the filaments so formed are drawn off. Subsequent treatment is so regulated that their surfaces ultimately reflect or disperse light in much the same way that a true silk filament does. This, of itself, is of little account, for glass will behave in this way. The threads formed of cellulose have additional properties which bring it in some respects almost into line with real silk. When it is stated that during the manufacturing stage the threads are more or less in a condition of a very firm jelly, it will be realised that the operations involved are necessarily unique in their nature.

Here we have to record a distinct advance in the technique of manufacture and incidentally in the value of the product obtained. It may be claimed that the chemist has played an important part in the development of this particular branch of the textile industry. It is obvious that without his work this industry could not have reached its commercial stage.

It will be seen that research is involved in the—

- (a) Actual solution of the cellulose.
- (b) The coagulating process.
- (c) After-treatment of the yarns, or filaments (denitration, etc.).
- (d) Recovery of by-products, solvents, etc.

The student will also remember that the methods of solution will naturally vary considerably, for cellulose may be dissolved by either the cupro-ammonium, or viscose process; or it

may be previously nitrated, or converted into cellulose acetate.

The details of manufacture are almost endless in their number and variety. The problems presented are those connected with colloidal solutions. They are present *in excelsis*, and must be controlled to a nicety, even when they are not understood. There is still work here for a number of chemists who have also some knowledge of physics and mechanics. It is difficult to think of a more promising field for technical research, for the prospects involved in the production of a more perfect filament or yarn are very considerable. The cost of experimenting is great, but the chief details which have brought success in the past have been more or less simple in their nature.

It is impossible to indicate the various methods employed to secure an even and satisfactory yarn. Many of these are of a secret nature, and their action still not understood. A mere indication of the nature of the machinery utilised may be derived by a careful study of the patent literature dealing with this subject.

Two examples only can be noticed here. In the Thiele system of manufacturing very fine threads, it is necessary first of all to coagulate the issuing stream of cellulose solution in a dilute coagulant. During this stage the thread, while in a semi-set condition, is subjected to a direct pull, and the filaments drawn out in this manner. It is then necessary to set the thread immediately by passing it into a stronger solution. In practice this operation may be conducted in the special tube illustrated in Fig. 6, which perhaps sufficiently explains itself.

In the second example chosen, a method of collecting the gelatinous threads is illustrated. The newly-formed thread passes down into the vessel shown in Fig. 7. This is rapidly revolved, and the thread consequently coils itself on the outer

surface of the same. At the same time the thread receives a spinning motion, and the individual filaments are bound together into a workable yarn. If this method is examined in detail it will be seen that it admirably serves its purpose. The threads are subsequently removed from the containing

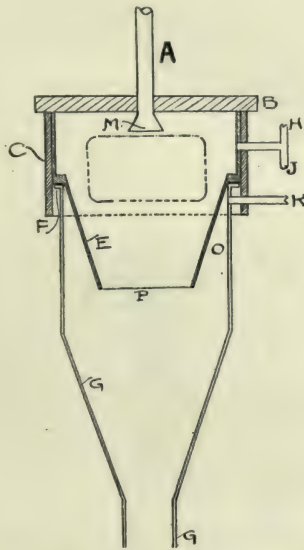


FIG. 6.—THIELE SYSTEM FOR SPINNING ARTIFICIAL SILK (DREAPER MODIFICATION).

vessel in a skein form, and are ready for washing or any other necessary operation.

Having once obtained satisfactory results with artificially produced yarns, a further step naturally suggested itself—viz., the possibility of manufacturing an artificial fabric without the intermediate process of weaving, winding, etc. Even this seemingly impossible task has been achieved. The difficulties to be overcome in this case are of a different

order to either of the other cases previously mentioned. Metal rolls have a pattern deeply engraved on their surface, which corresponds to that of the fabric to be imitated. A section of the roll as it revolves is "filled in" with cellulose solution. This is then automatically passed on into a coagulating bath, and the "fabric" so formed is carefully separated

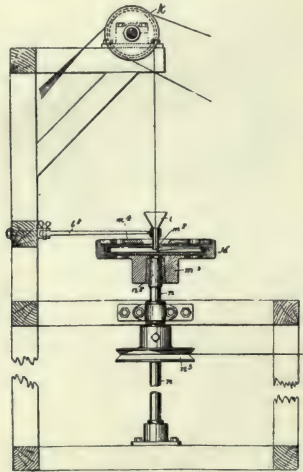


FIG. 7.—COLLECTING ARTIFICIAL SILK THREADS
(TOPHAM SYSTEM).

from the metal drum, wound off, washed, dyed and dried by special means. (Fig. 8.)

In Figs. 9 and 10 full-size reproductions of some of the materials manufactured by this process are seen, and in Fig. 11 a typical artificial silk composite thread.

Thus, in three cases mentioned, we have entirely different processes at work. In the first, yarns are produced from wood-pulp without solution. Secondly, where the cellulose material is actually brought into solution, and in the

third case, where a fabric itself is actually produced from a solution of cellulose without the intervention of any weaving process.

The last word has not been said, and future developments are, to an extent, in the hands of the chemist.

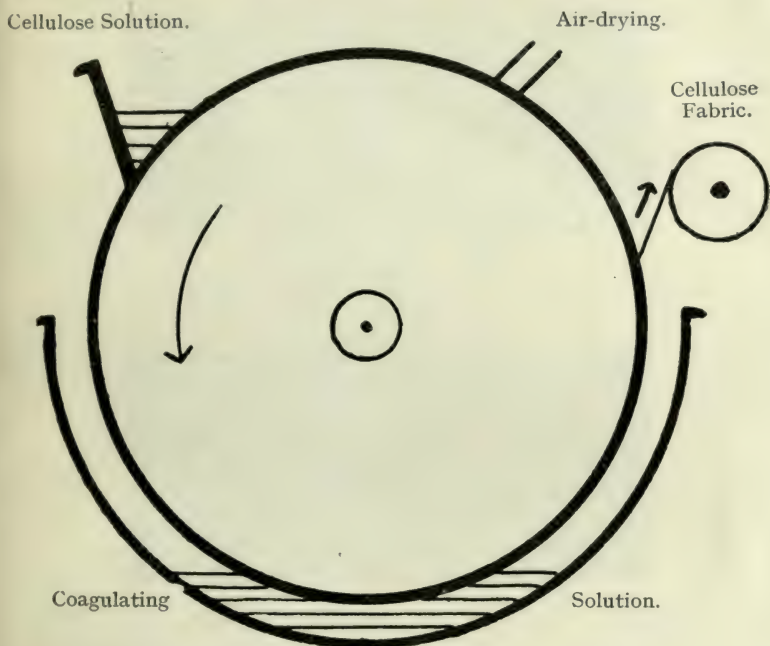


FIG. 8.—THE RATIGNIER AND PERVILLAC PROCESS.

It is unnecessary to point out that the work done in connection with the artificial production of aniline dyes has a special significance to the textile chemist. It might be interesting to consider how far the great advance recorded in this direction has been governed by the fact that research (apart from actual industrial operations) has closely followed the direction of investigation carried out in the colleges.

This industry has gained advantage over all others through the results of research in pure science, and this factor has undoubtedly helped the phenomenal advance in the manufacture of aniline dyes. Concentration in this direction has

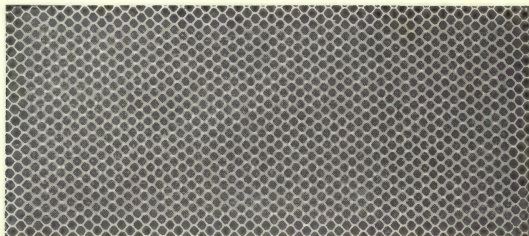


FIG. 9.—ARTIFICIAL CELLULOSE FABRIC (NATURAL SIZE).

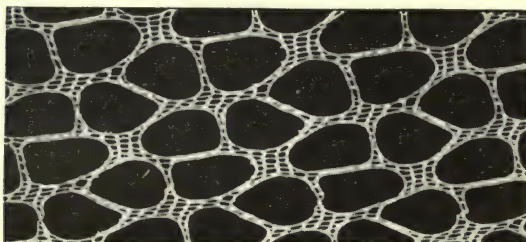


FIG. 10.—ARTIFICIAL CELLULOSE FABRIC (NATURAL SIZE).

possibly acted against a similar advance in theory in other branches of the textile industry.

As the Institute of Chemistry is practically confined to British chemists, it may not be out of place to record the recent advance in the manufacture of aniline dyes in this country. So important is this that English firms are now selling dye-stuffs on the Continent, and competing successfully in many neutral markets. This can hardly fail to encourage the further prosecution of industrial research in this country. The

recently expressed opinion "that science has become an industry" may certainly be applied in this case.

The manufacture of aniline dyes, however, has often been treated elsewhere, so we will rather consider how a chemist may make use of his knowledge in the actual operations of a textile factory.

One or two cases have been chosen, for the reason that the



FIG. II.—ARTIFICIAL SILK THREAD ($\times 80$).

problems met and dealt with can be readily indicated. These show that the chemist must be prepared to work on general lines, and afterwards, if he has the time or inclination, to develop a theory to explain the nature of the phenomena observed. This does not mean that experimental work should ever take the form of a succession of blind rushes, for success seldom comes to the investigator in this way. A carefully thought out programme is necessary, and as this must be

largely based upon past experience, the young investigator is naturally handicapped in this direction.

In the first case selected, the regulation of certain physical and chemical factors are in question.

In the manufacture of certain silk materials, known to the world as *crêpe de chine*, problems present themselves which are concerned with the production and *preservation* of effects produced at some intermediate stage in the

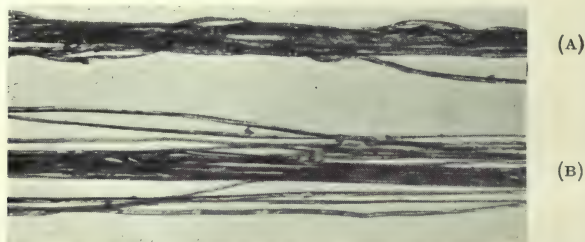


FIG. 12.—NATURAL SILK: (A) IN RAW STATE, (B) IN BOILED-OUT STATE ($\times 80$).

manufacture. All previous and after processes are arranged to that end.

In such materials, weaving takes place in the "gum." A raw silk thread, which contains about twenty-five per cent. of sericin or natural silk gum, is woven in the warp. In the weft, a raw silk thread is first spun and the thread as woven is highly twisted. In addition to this, the alternate weft threads as they occur in the woven fabric are twisted alternately to the right and left. The ultimate effect of this is to give a peculiar or irregular surface to the finished material. The threads in the warp, which are not twisted, open up under the subsequent influence of the "degumming" operation, which removes the encasing silk gum by the action of a hot solution of soap, so that a bundle of loose filaments finally

represents the warp threads. Fig. 12 shows a raw silk composite fibre, as is ordinarily used in the silk industry (A). The same thread is seen at (B) after the silk gum has been removed by the action of a boiling soap solution, and the individual filaments set free. The former thread is of a harsh and dull nature. The second one is brilliant and soft. To take full advantage of the properties of each

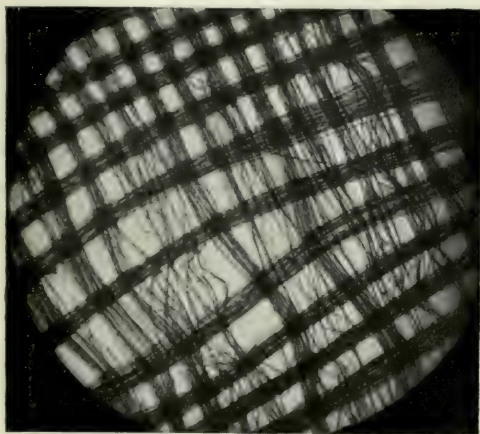


FIG. 13.—SILK FABRIC, EXHIBITING DAMAGE ($\times 30$).

condition, silk fabrics are often woven in the gum state and then subjected to the action of soap solution and the gum removed.

A common mechanical defect caused during dyeing or finishing operations is seen in Fig. 13. As the woven cloth enters the hot soap solution and the silk gum is softened, certain things happen to the weft threads. Being highly spun, they immediately contract in an irregular manner, and tend to form kinks at intervals. This is clearly seen in the accom-

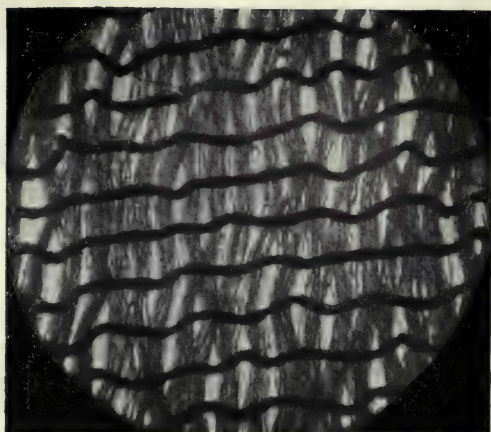


FIG. 14.—CRÊPE DE CHINE, SATISFACTORY FINISH
($\times 30$).

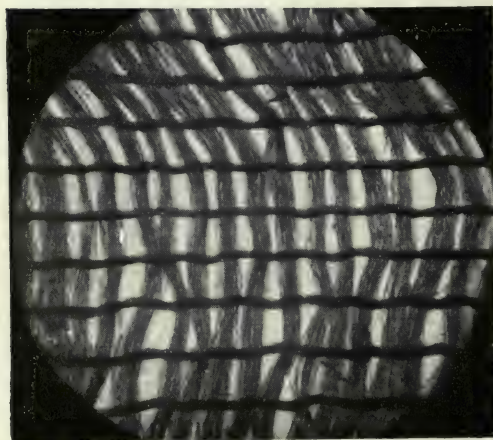


FIG. 15.—SAME MATERIAL, UNSATISFACTORY FINISH,
($\times 30$).

panying photo-micrographs (Figs. 14 and 15). In addition, the curling-up effect in any two adjacent threads tends to take place in opposite directions, owing to the threads being spun "right and left." The so-called "figure" is given to the cloth by the weft threads contracting irregularly, with the consequent displacement and opening up of the soft warp threads which cover them.

How can the chemist control or influence such operations? In a number of ways. First, the process involves a considerable knowledge of the action of alkaline solutions under different conditions of temperature and concentration upon the silk gum, and the consequent effect of its removal on the contractile power of the thread itself, which is influenced by its reduced diameter and substance. This again involves experimental work in connection with certain preliminary operations utilised to aid spinning and weaving operations. For instance, the subsequent effect of the steaming of the thread after spinning (which by its partial action on the silk gum prevents the kinking action coming into play before it is required) is a case in point.

The dissolving action of the soap solution on the silk gum introduces problems of a complicated nature connected with the behaviour of colloids.

Except under favourable conditions, which are closely connected with the chemical composition or physical state of the warp threads, these will not disperse themselves over the weft ones in the irregular manner desired. The ultimate value of the cloth will thus be determined by the control of certain preliminary operations as well as by the subsequent ones of "finishing," which are no less involved in their nature, from the chemist's point of view, and equally demand first-hand investigation.

A correct treatment of such a cloth will add greatly to its apparent value, which is naturally the standard the buyer

applies when purchasing. The different effects which may be produced in the same cloth are illustrated in the accompanying photo-micrographs (Figs. 14 and 15). Taken with transmitted light, their relative "covering power" or apparent value as produced under different conditions of treatment is indicated. Although the way to determine the best conditions of working may not at first sight be evident, yet it will actually be found that essential factors to success are of such a nature that a chemist can best deal with them.

In order that the surface of the fabric may be subjected to as little rough treatment as possible, when the harsh woven material is introduced into the boiling soap solution (which removes the silk gum from the thread and determines the contracted appearance which characterises this class of fabric), many different methods have been devised to give the cloth free play during contraction, and yet prevent it from "cracking" or creasing. It is at this stage that many defects are introduced which may be observed in the finished cloth. As an example of the methods employed a special frame which was devised to hold the cloth may be noticed. (Chedlow, Dreaper and Hall, Eng. Pat. 11,575, 1907.)

It was found that this frame could only be utilised when it was mounted on central pinions and given an intermittent swinging "to and fro" movement in the boiling soap solution. This example once more illustrates the point that successful working will generally depend upon some seemingly unimportant detail.

When the frame is moved through the required distance at its outer ends and is just about to move in the opposite direction, it must remain stationary at this point for a period of some seconds. The individual folds of the fabric then continue to move in the original direction, and open up in such a way that the required fresh supply of soap solution comes in contact with all parts of the fabric, and effects the complete

removal of the "silk gum" in the shortest possible time. Any silk gum remaining in the fabric has a special affinity for dye-stuffs, so that uneven dyeing will result. Its presence also prevents the silk filaments making up the warp threads from spreading out in the desired manner. Again, if the treatment of "boiling out" is unduly extended, the silk fibre itself will suffer from a want of lustre owing to hydrolysis and consequent disintegration of the surface of the silk filaments. Working conditions must be so arranged that all these points are considered.

When once the silk gum has been removed and the maximum "contraction" obtained, subsequent operations are far less likely to damage the material, for it is then in a soft condition. The chemist may determine the correct relationship between the contracting power of the threads as represented by the amount of twist given to the silk threads in its relation to subsequent removal of silk gum, and deal with many other operations involved. In materials where only part of the fabric contracts, the problem is possibly still more complicated.

Theory and Practice.—It is an easy thing to trace the work of the chemist, and his influence on the textile industry.

A case will now be instanced where theory alone has offered an explanation of certain difficulties which have given endless trouble in the past. More important still, it has pointed the way to their removal.

The occurrence of free acid in certain silk or wool materials had often been noticed, but could not be traced to its origin. Its presence led to disastrous results.

Silk will absorb free acid with great avidity from aqueous solutions. Practically all the acid may be taken up by the fibre within a few minutes. Free sulphuric acid had often been found to be present in silk fabrics, which had not come in contact with it during the process of manufacture. After

a period of some months, such materials developed brown stains and lost their strength.

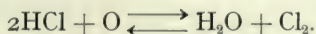
When these materials were repeatedly found discoloured on storage, and to contain free sulphuric acid in comparatively large amount, only one course remained, viz., to conclude that the dyer was still using it in his operations. There is one inevitable rule in a textile factory, "When in doubt, blame the dyer." Theory has since indicated that free sulphuric acid may be present in the finished fabric, without it being utilised in dyeing.

The mystery, and it remained one for several years, has been cleared up by an application of the so-called "neutral salt" reaction. If sodium sulphate is added to a dilute acetic acid solution, there is distinct evidence from the colour changes which occur in the presence of indicators, that an equilibrium is established under which free sulphuric acid is present in the solution. The amount of free sulphuric acid may be small, but the avidity with which this acid is absorbed by silk at ordinary temperatures will be remembered. Given an equilibrium of this nature, the free acid present in the solution may be absorbed by the silk fibre and removed, when a further amount will be once more set free in the solution by the same reaction. A state may be ultimately reached, at which a comparatively large amount of free sulphuric acid will be found within the fibre area. There is, unfortunately, an additional tendency (due to certain finishing or dyeing operations) for this acid to concentrate still further over certain areas of the fabric.

Thus, if dyeing operations be conducted with acetic or formic acid, and the water contains soluble sulphates, free sulphuric acid may be observed in the fibre. There is sufficient evidence available to show that this action takes place, and the example given is interesting, as it also confirms a point in general theory which has given rise to much discussion

in the past. In the case of cotton and wool mixed goods, the acid set free by the animal fibre may be, in some way or other, subsequently transferred to the cotton fibre, which then entirely loses its strength.

In other cases, the presence of chlorides has undoubtedly produced stains. I have suggested elsewhere that the production of chloramines may be the cause of this defect. In the presence of water and oxygen it is known that hydrochloric acid may actually be present in aqueous solutions, and that then the following reversible action may take place :—



It is, therefore, conceivable that a small amount of free chlorine may be present in the silk fibre. The further production of chloramine compounds, through reaction with the amine compounds in the fibre, is possible. This, in its turn, may decompose and again set free hydrochloric acid. This reaction is known to take place with mono-chloramine (NH_2Cl). Raschig (*Ber.*, 1907, 40, 4586) has shown that only in the presence of gelatin can hydrazine be produced. It is known also that even sulphurous acid will decompose chloramine compounds. The presence of acetic or formic acid may thus alternatively lead to the production of free hydrochloric acid or chlorine, and one of these may directly or indirectly be the cause of the defect. As these acids are so commonly used in silk dyeing, it is possible that the staining action may be started in this way. It will be seen that further investigation promises to throw light upon this vexed question, and that these experiments have an interest outside the sphere of dyeing.

In dealing with the nature of dyeing operations, a simple experiment at once indicates that the adsorption of dyes is a general one, and not necessarily characterised by the presence of a fibre substance.

If a solution of Night Blue is allowed to percolate through a sand column, the whole of the dye may be retained. This reaction is a quantitative one as estimated by the volume of colourless solution which passes through the sand. It may also be shown that a column of finely chopped up silk, or cotton, can be substituted for the sand with similar results.

When the dyeing action takes place in an alcohol-water

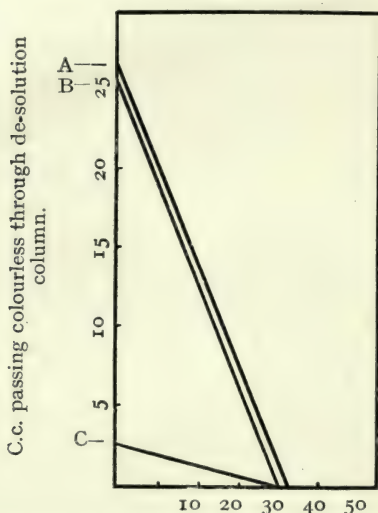


FIG. 16.—% ALCOHOL (BY VOLUME) IN DYE SOLUTION.

system, an increase in alcohol reduces the amount of dye absorbed by silk, cotton, or sand. The result may be expressed as straight line curves, showing that *under the conditions indicated* the dyeing action is of the same order in all cases. With 40 per cent. alcohol (by volume), absorption is entirely prevented in all three cases. Thus the action closely follows the solution state of the dye.

The curves A, B, and C in Fig. 16 are those obtained with

silk, cotton, and sand respectively, and they clearly indicate the results.

After adsorption has once taken place, a treatment with alcohol will completely remove the dye. When this solution is evaporated to dryness, the dye-stuff is found to be quite insoluble in water. It is evidently now a highly basic hydrochloride, for the colourless aqueous solution passing through the sand column is acid to litmus paper. A passage through the sand column has altered the chemical composition of the dye-stuff, as well as retained it.

Dyeing is, therefore, not necessarily connected with fibres; and such a material as sand is capable of acting in a manner calculated to upset many of the older theories concerning its nature.

That a textile fibre may decompose a dye-stuff such as an hydrochloride, is no longer accepted as evidence that the fibre substance plays an essential part in the reaction. At one time such results were regarded as absolute proof that the fibre substance entered into chemical combination with the dye-stuff.

The student in general chemistry will allow that it is difficult to call to mind many reactions which more clearly demonstrate the effect produced by surface action, than those of the sand column. Owing to the high tinctorial power of dye-stuffs, it is possible to detect and follow the course of the reactions involved with surprising accuracy. Thus, the results obtained in the absorption of Night Blue by sand gave the following figures:—

Ratio—dye/sand	1/0·000148
„ „	1/0·000147
„ „	1/0·000148

These results represent a high water mark of accuracy for reactions proceeding in aqueous solutions. As the dye

solution passes through the sand column the final change from a colourless to a coloured solution, as it leaves the column, is observed in the passing of two successive drops of the solution.

I will now draw your attention to further experiments which illustrate some of the difficulties to be met, when explaining the actions involved in dyeing. In practically all the cases selected, research had its origin in some observation made in the dye-house.

Certain dye-stuffs are so sensitive to changes in colour, in the presence of acids or alkalies, that they are commonly used as indicators. In a series of experiments which have been described elsewhere (Dreaper and Wilson, *J. S. C. I.*, 1909, 28, 57), differences in the colour changes which take place when such dye-stuffs are present within the fibre tend to throw further light on the action of dyeing. I would particularly draw attention to certain experiments with Benzo-purpurin 4 β , which is termed a direct or cotton scarlet dye because it dyes cotton as well as silk.

In the presence of acid, the colour of this dye may change to a purple, or even black, shade. When silk or cotton respectively is dyed, and introduced into an acid solution, the ordinary change in colour takes place, but only in a relatively concentrated acid solution. This difference suggests a measure of the attraction between the dye and fibre. When the dyed fibre is partly changed from red to black under the action of the acid (N/50 sulphuric acid) and is raised in temperature by heating the acid solution in which it still rests, further changes occur. With animal fibres, the shade tends to return to its original scarlet: while in the case of vegetable fibres the change in colour due to acid increases, and the dyed fibre becomes almost black.

Although this result is somewhat disconcerting, it may be argued that the affinity between the dye-substance and the

animal fibre (of whatever nature it may be) is increased with temperature, for no corresponding change in colour of the acid dye solution takes place ; on the other hand, this attraction may decrease with temperature in the case of a vegetable fibre, but it is probable in view of other experiments that this is not an absolute reaction.

It may be noted that similar results to those obtained with animal fibres have also been recorded by Bayliss when " dyeing " hydrated alumina. It is claimed that in this case, also, there is distinct evidence that the dye-stuff is first absorbed by the alumina, as shown by the colour changes observed, and then enters into a closer combination at higher temperatures. So that the general effect may be of the same order in both cases.

Experiments in other directions indicate that with both vegetable and animal fibres, the dye-stuff and fibre may show a closer relationship when dyeing takes place at higher temperatures, if the mutual attraction between dye-stuff and fibre is measured by the subsequent resistance against the solvent action of certain solutions on the dye present within the fibre area. To illustrate this method of attack, the results obtained when silk is dyed with acid anthracene Red 3 β may be instanced. The dyed samples were then subjected to the solvent action of alcohol or soap solution. Results recorded elsewhere indicate that higher temperatures in dyeing greatly increase the resistance of dye against de-solution. This has, of course, an important bearing on the practice of dyeing.

Such dyes as Night Blue or Primuline Red (developed), which give such remarkably fast results, are not fast if dyed at low temperatures, although no difference in shade can be detected. Similar results are obtained when cotton is dyed with Benzopurpurin 4 β at varying temperatures.

On these results, an interesting test has been founded.

If a silk fibre is dyed at 60° C. and then introduced into water at 60° C., no loss of colour will take place. But if the temperature is 70° C. the dye will partly "bleed" off. It is possible, in some cases, to find out at what temperature the silk was originally dyed—an important point in some cases. This is one of the methods of testing previously indicated, which are not generally recorded in the journals.

The next experiment indicates the reactivity of the fibre, in certain cases, from which one might reasonably assume that dyeing may involve chemical action. Two samples of silk are taken. The first one has been dyed with one per cent. Primuline, which, as you know, is capable of being diazotised on the fibre and then coupled with β -naphthol to produce a scarlet dye, which is remarkable for its resistance against the action of boiling soap solution.

The second sample has not been dyed with Primuline, but only placed in a solution of nitrous acid, similar to that used to diazotise the other sample, and then in that of β -naphthol. Both samples then take equally dark shades of scarlet, the *undyed silk* as well as the dyed one. It is obvious that the silk fibre contains a substance which reacts with nitrous acid, and then gives a bright scarlet shade with β -naphthol.

These last experiments sufficiently demonstrate that a great deal of work must still be carried out before the exact nature of dyeing can be determined. Even if the relationship between the dye and fibre is, what is termed, physical, it probably depends upon something which can be regarded as equivalent to residual affinity. This may vary in a remarkable manner according to the temperature at which dye-stuff and fibre are brought together.

Having dealt with these simple experiments, attention may be drawn to a list of the probable actions which may be involved during dyeing operations, which I advanced some time ago.

- (1) A solution state of the dye within certain limits of aggregation as determined by the laws of solution.
- (2) A fibre state corresponding to this state of aggregation and of a permeable nature.
- (3) Localisation of dye-stuff within the fibre area through surface concentration effects.
- (4) Localisation of salts, acids, etc. (assistants), within the fibre area from the same cause.
- (5) The direct entrance of dye aggregates by molecular migration, with subsequent reformation of aggregates within the fibre area.
- (6) De-solution, due to surface concentration effects ("salting out"), or secondary attraction, between the fibre substance and the dyes.
- (7) Primary or chemical action, which may play some part at this stage, and may even in some cases take the place of, or cause, de-solution phenomena.
- (8) De-solution effects in the case of basic dyes, which may lead to alteration in constitution, and the production of basic salts in a state of high molecular aggregation (insoluble) within the fibre area.

In recent years, Perrin has suggested that the action of dyeing is a purely electrical phenomena, and this suggestion has been followed up in some detail by Gee and Harrison in this country. The dye is supposed to be attracted to the surface of the fibre owing to differences in potential, which have been observed when a solid is brought in contact with a liquid. Thus, one can imagine that if the fibres show a + sign, it will attract a dye-stuff which possesses a - sign, and that the dye-stuff will leave the solution and attach itself to the fibre. This may possibly explain the phenomenon which has been known as surface concentration or attraction, but, on the other hand, the latter may be due to the action of residual affinity. Here, again, observation of the results

obtained is comparatively easy, owing to the high tinctorial power of the dyes themselves. Such considerations suggest that the reactions which occur in dyeing are worthy of a good deal more attention on the part of the general chemist than they have received in the past. The results have possibly been obscured by the greater immediate success and bearing on the theory of the reactions involved in the actual manufacture of synthetic dye-stuffs. With a further advance, which is now due, the chemistry and physics of dyeing will certainly claim more attention than in the past.

It may be argued that our want of knowledge of the chemical constitution of the fibres has mitigated against the recognition of much of the work done in this direction. It must be remembered, however, that it is possible to prepare cellulose in a fairly pure condition, and also that the general nature of the results obtained may be confirmed by sand column experiments and others of a similar order. Thus, to a great extent, this disturbing factor may be allowed for, even if it cannot be entirely eliminated.

Much has also been done by Pelet-Jolivet and others to prove that dyeing, at one stage at any rate, is purely an adsorption phenomenon.

Practical Difficulties.—To indicate the difficulties which may be met with, a case may be mentioned which remains at present unexplained. In certain silk goods, it is observed that when great care is not taken during the "boiling-off" operations, white marks will appear on the finished goods. Under the microscope, these are resolved into bundles of frayed or broken filaments which occur on the surface of the cloth. It is known that this defect occurs after the weaving process, for it can be eliminated by careful handling in the "boiling-off" process.

When the cloth is subsequently dyed a dark shade, these broken ends seemingly remain white. All attempts to

cover them by dyeing are unavailing. It is obvious that the explanation of this phenomenon, when it comes, may throw some light upon the nature of dyeing. It seems to me that there are two possible explanations for this action. If dyeing is primarily an electrical phenomenon, it may be that the action is due to some modification of the Perrin effect within this area. Or it may be, as I have before suggested, that, at the time of fracture, the internal structure of the filament is so modified physically that it is no longer pervious to dye-stuffs or their solutions. This example indicates the call for a considerable knowledge of theory when dealing with many of the reactions involved in the everyday work of a textile factory.

That the relationship which exists between the dye-stuff and fibre substance is dependent, within certain limits, on the temperature of the dye solution is important, for it is difficult to imagine that such a phenomenon is confined to those compounds which exhibit tinctorial properties.

Embossing.—This operation produces by mechanical means a definite pattern on a plain fabric. Effects can be produced which, in the ordinary way, would be obtained by very complicated weaving. In the production of certain fabrics, this process has been carried to somewhere near visual perfection, but unfortunately materials thus treated have not, as a rule, the wearing properties of those in which the design enters into its substance.

An application of particular interest in this country is the manufacture of mourning crape, which is still largely exported to the Continent, where it has a considerable vogue.

Owing to the exclusive nature of the processes involved, its history has yet to be written. One or two points may, however, be considered, as these illustrate in an interesting manner the development which may take place in the manufacture of a textile material.

Crape was originally imported from China. Since its

introduction into this country it has been altered beyond recognition. The original material was obtained by the simple operation of steeping a "raw" silk gauze, the threads of which had been highly twisted, in water. Under these conditions an irregular-surfaced material was obtained.

Somewhere about the year 1830, a Huguenot weaver in the district of Tottenham attempted to improve the cloth by symbolically representing on its surface "the tears of the mourners." The method used to attain this end was peculiar, and worthy of record. Taking a fisherman's net, he reduced its width and lengthened its mesh by pulling, and passed it with the silk fabric through a pair of plain rollers. So far as I know, no sample of this crape is in existence to-day. The knots and threads were imprinted on the surface of the fabric. It must have met with success, for attempts were subsequently made to engrave the required design on one of the plain rolls, through which the netting and the silk fabric had previously passed. The next step was to cut the design more deeply into the roll. Some time later, the second roll became a paper one, which was subsequently "worked up" against the metal one on which the design was set out. The embossing effect produced was materially deepened. The type of an ordinary embossing machine is very similar to that used for Schreinerling.

Without entering into the details of its modern manufacture, which entail an exceedingly complicated sequence of operations in order that the embossed effect may be retained during subsequent processes of dyeing, dressing, waterproofing, etc., certain of these operations entail the same principle as that adopted in the Tottenham fishing-net experiments, and are still an essential factor.

It is an open secret that, under modern conditions, the embossing takes place at a high temperature and pressure, and that the "silk gum" is materially modified in its physical

and possibly chemical properties. By the regulation of an ordered sequence of processes, which is practically unparalleled in textile work, the modern product is obtained. In such manufactures, the chemist may find at almost every turn, problems which demand close attention. When it is remembered that, in the finished state, this material may, if imperfectly finished, sell at less than half its full value, it will be realised that there is always a definite call for improvements in detail, in what is already an exceedingly complicated process.

The so-called process of "Watering," which gives a peculiar appearance on heavy silk fabrics, is a simpler operation. It is interesting to note here, that this process probably had its origin in an attempt to record permanently on a fabric, the effects observed when an exceedingly fine silk gauze material is folded layer upon layer so that they touch at certain points. Under these conditions peculiar optical effects may be observed on examining the fabric, which are obviously due to the play of light as it is caught and reflected from the superimposed silk threads. It is this effect which has been copied on heavier materials by embossing.

Raw Materials.—Under present conditions, the chemist has not much to say concerning the purchase of raw materials in the shape of textile fibres. This condition is likely to change in the future, for several reasons. It is true that purchases are more and more based upon the amount of moisture present in the more expensive fibres, and that to-day the "conditioning" of silk is practically universal. Many of the textile books state that moisture up to even 30 per cent. may be introduced into raw silk without this being recognised by its feel. This is probably an exaggeration. The actual conditioning of silk is concerned with variations of from 1 to 2 per cent. from 11 per cent. which is now universally recognised as a standard. As silk may sell at say eighteen

shillings a pound, it will be seen that on a purchase of 1,000 lbs. an increase of even one per cent. in moisture will mean a loss to the buyer of 10 lbs. of silk on its delivery. Thus, conditioning stations have been established in many centres and, in their modern usage, may deal with other factors than the percentage of moisture present in textile fibres. Such stations may be found at Manchester and Bradford in this country. (Fig. 17.)



FIG. 17.—YARN TESTING (BRADFORD TECHNICAL COLLEGE).

It is only in certain cases that the chemist has a voice in the purchase of textile fibres, when certain physical or even chemical factors are recognised as being in question.

The need for such supervision may be seen in the agitation which has been actively carried on by trade associations and others concerning the methods used in South Africa in the dipping of sheep.

For some reason best known to the authorities, a sheep dip is officially recommended which consists of a mixture of slaked lime and caustic soda. The effect of this on the wool itself

is sufficiently injurious, for the selling price of South African wool to be materially affected, and endless trouble introduced in subsequent manufacturing processes.

It is said that the breaking strength tests show a loss of 18 per cent. in the treated wool. Although wool buyers and English Chambers of Commerce have protested since 1899 against this treatment, it is still carried on, and the directions, issued in the *Government Journal of the Union of South Africa* as recently as March, 1913, still recommend its use, and give particulars of its preparation.

This example must be the only one which can be discussed on the present occasion. Many of the methods used to determine certain differences in the nature of raw materials which count in the subsequent manufacture, as they have been noted, or even controlled, by chemists are considered to be of a more or less secret nature.

Bleaching.—It is impossible here to enter fully into the subject of bleaching, and my remarks must be confined almost entirely to cotton, and even then to the electrolytic bleaching process. This is rapidly coming into use in certain directions, and may ultimately oust the original chloride of lime process. The electrolytic bleaching process possesses one great advantage. Sodium hypochlorite is used in the place of the ordinary calcium compounds. In the artificial silk industry its use is practically universal. The nature of the solutions and the satisfactory action of the solution as freshly prepared give this an advantage over the older process.

Although woollen goods are not bleached with chlorine compounds, a treatment with chlorine will prevent subsequent shrinkage. In this direction the electrolytic sodium hyposulphite solution also gives superior results, producing a softer and more desirable yarn. The action of chlorine on wool is very rapid; practically the whole of the chlorine in the bath being absorbed within two minutes.

Although we are not directly concerned this evening with the re-bleaching of goods, the use of electrolytic bleaching liquors may be strongly recommended for the laundry trade.

As the sodium hypochlorite leaves the electrolyser it gives better bleaching with weak solutions than the older bleaching liquor does with strong ones. Two of the best known types of electrolyzers are those of Kellner, and that sold by Messrs. Mather and Platt. In the modern type, the original salt or brine solution passes in a serpentine course between the platinum or carbon electrodes. The salt employed in the solution is never entirely converted on grounds of economy, and care has to be taken to adjust the cost of current to that of the salt to secure economical results. Under present conditions, the cost of electrical energy must be low, but in view of the many advantages which the use of the sodium salt gives the bleacher, the new process will obviously be put to more extended use. This subject is one to which the young textile chemist would do well to pay special attention. Messrs. Siemens and Halske claim to have put in plant for bleachers which in the aggregate utilises over 1,000 H.P.

Electrolytic bleaching has been under a cloud, owing to the introduction of many unsuitable types of electrolyzers, most of them costly in their nature and low in efficiency; but it is certain that this method of preparing bleaching solutions will extend in the near future.

Hydrogen peroxide plays an increasing part in the bleaching of animal fibres, and sodium peroxide and the perborates have come into use as substitutes for this reagent. The residual tint which is nearly always left after bleaching is corrected by tinting with a minute amount of a suitable violet dye. "Dead white" shades can be obtained in this manner. Many of the details connected with bleaching operations may be considered from the chemical point of view. It is likely that many improvements in detail will still be worked out

in spite of the technical excellence of the results already obtained. The introduction of electrical bleaching indicates the call for a wide knowledge on the part of the textile chemist.

The three chief processes in vogue to-day for the bleaching of cotton goods will be seen illustrated in Figs. 18, 19 and 20. The different nature of the machinery utilised will at once be realised. A good deal of the detail work connected with

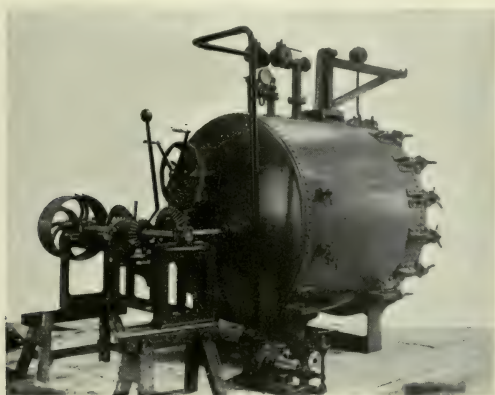


FIG. 18.—COTTON BLEACHING KIER (MATHER AND PLATT SYSTEM)

this process has been worked out by the three firms responsible for the methods shown—viz., Messrs. Mather and Platt, Messrs. Jackson Brothers, and Messrs. Edmundston. It will be realised that in all cases the object in view is the production of a pure cellulose product which will supply a material of even nature to the action of dyes, etc. A reference to samples of the cloth in the different stages of bleaching will indicate this point.

The many operations connected with the treatment of textile fibres or woven materials may be roughly divided

under the headings of preparing, bleaching, dyeing, printing, and finishing. In each of these, innumerable processes and methods are in use. The machinery or methods utilised are sometimes common to the whole trade or may be only utilised in a single works. Even when the former is the case, it is rather remarkable that no two works are conducted on identical lines, but each varies materially so far as detail is concerned. This is possibly due to the continual state of change which has

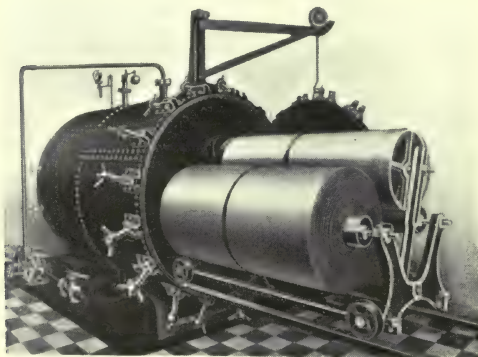


FIG. 19—COTTON BLEACHING KIER (JACKSON SYSTEM).

been experienced in this industry of recent years, though local conditions are also involved.

The modern investigator has made use of many processes which may rightly be regarded as non-textile in their nature. It is not generally possible to discuss these in any detail, as they are often worked as secret processes. Mention might, however, be made of the influence certain electrotyping operations have exerted in this direction ; and also of the fact that these have demanded the working out of modifications in procedure which are not generally known to the electrotyping trade itself.

When one compares the raw material with the finished product, the results obtained under modern conditions are astonishing: results not carried out on a laboratory scale, but proceeding on a scale of hundreds of tons, under factory conditions.

The skill of manipulation involved is equally surprising in its excellence, especially when it is realised that the raw

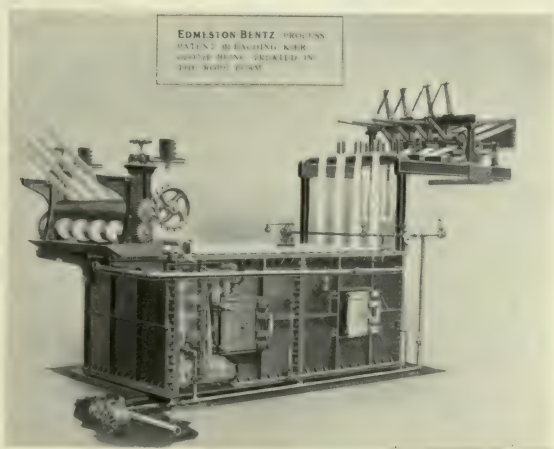


FIG. 20.—COTTON BLEACHING KIER (EDMISTON-BENTZ SYSTEM).

materials are not “pure for analysis,” but are subject to constant variation, which can only be realised when they are exhibited for the first time in some intermediate stage of manufacture. The chemist will soon realise how important the foreman’s work is, for he has, on the spur of the moment, to rectify such conditions and, by the aid of past experience, prevent, by differences in treatment, such defects from being observed in the finished product.

From the dull, harsh, “raw” silk are produced fabrics

of the softest nature and great brilliancy: from raw cotton, a finished product which can hardly be distinguished from certain silk or wool materials.

From wood-pulp by actual solution and subsequent reprecipitation, even fabrics of the greatest brilliancy may be produced, which, in some respects, are the equal of the woven materials themselves.

The work for the chemist in such operations may be gauged by his influence in the past. Many of these modern processes

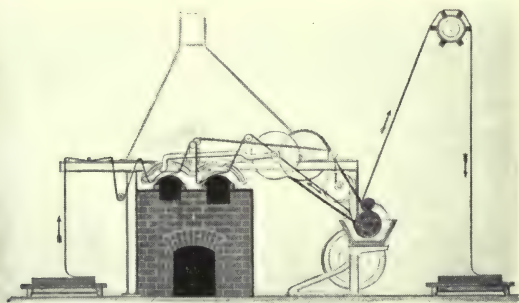


FIG. 21.—HOT PLATE SINGEING (MATHER AND PLATT).

are primarily chemical in their nature, and have been proposed and worked out by chemists.

One might consider in this respect the modern developments in silk weighting. Silk weighted with tin compounds has had a sinister reputation. It has been known to fall to pieces through subsequent changes which may occur on storage. Under modern conditions, and through the work of the chemist, this defect has been greatly minimised. The question, however, remains an open one—how far a material which may contain an added 100 per cent. of inorganic material can be called silk?

If the student will follow the instructions given in some

standard text-book for the weighting of black silk to, say, 100 per cent., the results obtained will certainly indicate the value of actual experience in such matters. Either a fair amount of weighting and a fibre which looks more like tow than silk will be obtained ; or, possibly, no weighting to speak of, and a tangled mass of fibre in place of the original skein.

Many factors are involved in such operations. The nature of the water supply is so important that it is said that one of the largest concerns connected with the weighting of silk only succeeded when, for certain reasons, their works was removed a few miles from the original site, and an entirely different water supply was secured.

One of the most important operations connected with the final finishing of cotton goods is that known as "singeing." In this operation the cloth is rapidly passed over a copper surface brought to redness and the loose fibres destroyed by heat ; or else the cloth is rapidly passed through a gas flame. The actual method adopted is seen in Fig. 21.

In many operations it is useful to be able to regulate the temperature of dye solutions automatically. This can be achieved in several ways. In Fig. 22 the Baldwin thermo-regulator, which is designed on lines involving an electrical control, is illustrated.

It is a mistake, however, to imagine that the chemist's work in the textile industry is chiefly concerned with the adulteration of material and supplying the public with something which is not what it appears to be. Such work is mainly constructive, and its influence has been for good. Extraordinary results have been achieved in the last twenty years in the direction of actual improvements in manufacture as well as in the cheapening of production.

By way of illustrating the varied nature of the operations involved in textile work, the recent use of malt extract, or the enzymes contained in it, for removing starch from cotton

fabrics may be cited. The warp threads in a cotton material are subjected during weaving to continual strain and friction. To reduce this disturbing effect to a minimum, the cotton yarns comprising the threads in the same are sized with starch. Before bleaching the resulting fabric it is necessary

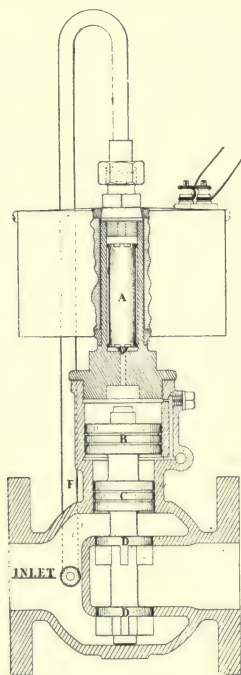


FIG. 22.—BALDWIN THERMO-REGULATOR.

to remove this substance, and malt extract is now largely used for this purpose.

It may be mentioned in passing that this new development has brought about novel conditions in the analysis of malt extracts, and the Society of Dyers and Colourists has appointed a committee to examine the position. Processes utilised in



FIG. 23.—TESTING BALLOON FABRICS (NATURAL PHYSICAL LABORATORY).

the brewing industry for its analysis have little value in the textile industry; and special methods have to be devised to meet this new condition. In addition to its starch-removing properties, malt extract has other uses in the textile industry.

The waterproofing of fabrics under modern conditions is an operation to which the chemist must pay particular attention. In some cases a spot-proof material is desired, and, in this case, entirely different methods must be adopted to those used where a material is required which is waterproof, but not air-proof. In the latter case, aluminium salts are generally used. Solutions of cellulose acetate may take the place of collodion in the treatment of fabrics. Waterproofing is a branch in itself, in the same way that the preparation of artificial leather cloth is, and requires a considerable knowledge of practical working conditions before it can be successfully dealt with by the chemist.

In the production of gas-tight fabrics, other conditions prevail. In this case rubber, in some form, is always used; and the production of a material which will pass the standard set up at the National Physical Laboratory, or elsewhere, is a matter of considerable difficulty. (Fig. 23.)

In recent years, a good deal of attention has been given to the question of fire-proofing fabrics. An Act comes into force from the New Year which deals with the misdescription of non-inflammable fabrics. It is specially in the direction of flannelette that further work is required. The problem here is not a simple one, for the material must remain fireproof after many visits to the laundry.

A few words may now be said concerning the processes in vogue in printing, which is conducted on a large scale in the cotton industry and also on wool and silk. The detail connected with these operations is such that it is possible only to touch upon it this evening. The Swaisland Printing Works will be good enough to demonstrate to you the

nature of hand block printing, which still has a vogue in certain directions and produces results which cannot be equalled by machine printing. Another interesting method of printing is that known as Aerograph work. This will also be shown this evening. In this case, the colour is pro-

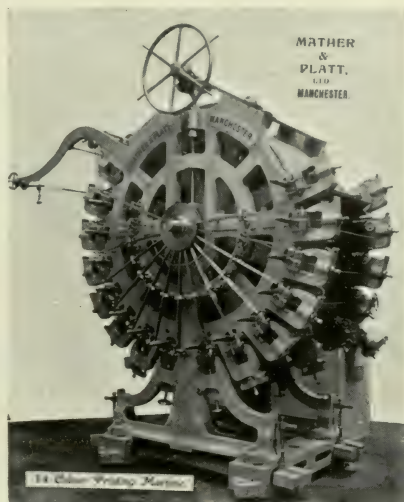


FIG. 24.—I4 COLOUR PRINTING MACHINE.

jected on to the fabric by spraying, and novel results can be obtained.

In machine printing, the machinery is complicated (Fig. 24); and attention may be directed to the equipment set up for instruction in printing, etc., in the Manchester School of Technology, shown in Fig. 25. This, with that shown of the Bradford Technical College Dyeing Department (Fig. 1), gives some idea of the nature of the training imparted in these technical schools.

Some of the types of machinery utilised in the finishing of

textile materials are of considerable interest to the chemist, for the nature of many of the reactions which take place in certain finishing operations is still undetermined. It is often connected with the state of hydration of the materials, or the action of steam and pressure on the surface of the fibres. A great deal of work remains in this direction for the chemist. The methods adopted in the even spraying of goods with water

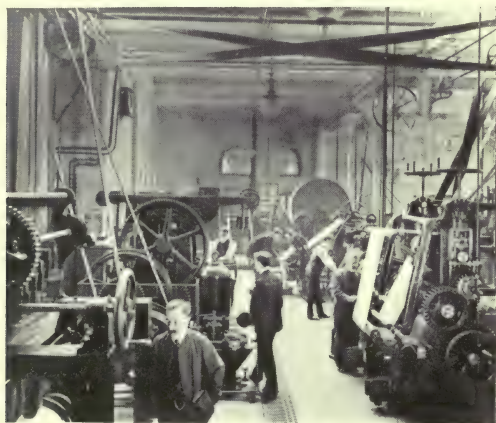


FIG. 25.—FINISHING MACHINERY (MANCHESTER MUNICIPAL SCHOOL .

are also important. The actual method adopted is seen in Fig. 26.

In some cases, when it is desired to obtain a cloth containing a dressing material to give it body, and at the same time not harsh to the feel, the fabric is subsequently treated in a beetling machine, which subjects it to a series of knocks to soften it. (Fig. 27.)

Fur Dyeing.—This branch of the industry is of special interest to the student, for the methods utilised are different to those adopted in general dyeing. Generally speaking, the

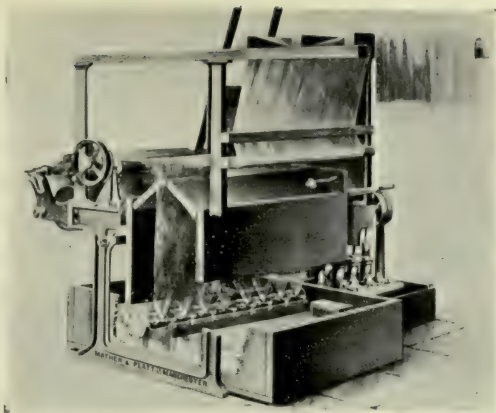


FIG. 26.—SPRAYING TEXTILE FABRICS (MATHER AND PLATT).

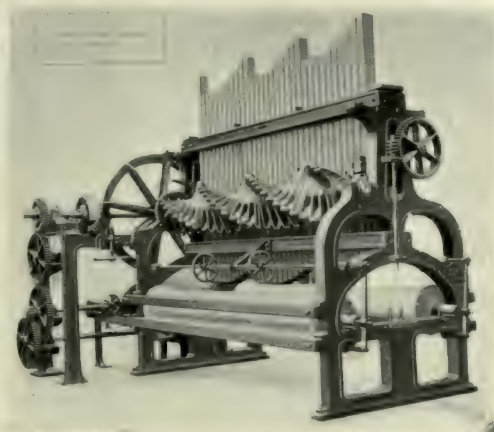


FIG. 27.—BEETLING MACHINE (EDMESTON).

substances which impart colour to these materials are produced *in situ*. For example, a fur may first be treated with a solution of *m*-phenylene diamine and then subjected to the action of hydrogen peroxide, when the colouring matter is produced. Probably, although this matter has not been studied in detail so far as I am aware, variations in temperature in the first process have a definite influence on the fastness of the colour produced against rubbing, etc., as in the case of textile fibres.

Influence of Moisture and Heat.—It will be gathered from the remarks made generally in these lectures, that the influence of moisture, in its relation to the many operations of finishing adopted in this industry, is paramount. It is probably the most important influence which the investigator has to consider. The presence of moisture in a fibre gives rise to many conditions, which seem to indicate that it is present in more than one condition. This materially adds to the difficulty in determining its true influence. The fact that all the fibres take up moisture, and that this influences them in different ways, is one of the most perplexing problems met with in this industry. It will probably be many years before this matter is properly understood, or explained scientifically; but when this is achieved, light will undoubtedly be thrown on many phenomena which are so obscure to-day; and which, under present conditions, can only be dealt with on empirical lines.

Chemist and Engineer.—The relative position of the chemist and engineer in the works has given rise to discussion in the past, and still shows signs of not being altogether understood.

The opposition to the chemist which is said to exist in some quarters has probably been much over-estimated. In the majority of cases the chemist obtains all the necessary aid he may require from the engineering department. As a matter of fact, the engineer always seems interested in the

chemist's work. This is due, no doubt, to the different method of attack adopted by the latter, which, in itself, fully justifies the presence of the chemist in any works.

Under normal conditions the engineer frankly helps the chemist in his experimental work, and this aid is of real service in many ways. Quite apart from his previous training, the chemist will pick up a fair knowledge on the engineering side in the works, which will be particularly useful in cases where he subsequently acts as manager of a department, or even of the works itself.

The chemist should be just as anxious to make friends with the engineer as with the heads of other departments ; and the best way to gain experience and knowledge in this direction is to keep in touch with any new experimental plant which may be in course of erection.

In some cases, work will develop in directions which are not naturally covered by any existing department. If the operations involved are complicated, it may be better for the process to remain under his direct management or control. In this case, one or more experimental departments may, in time, be associated with the laboratory.

It is then necessary to borrow men from the engineering department, and to direct their operations. When this happens, the work of the chemist becomes still more general in its nature, and additional experience is gained in the management of men and processes.

Where experimental work is rapidly translated into full scale operations under normal conditions, the control will pass to one of the works departments. This should be encouraged, for the chemist is then more free to continue research in any other directions which may present themselves. But he must always be ready, and able, to resume temporary control if things go wrong, or where further developments are in progress. Under proper conditions, the foremen will not object to this ;

nor will the engineer. Both will be too busy with their own work to worry about such matters.

Power and Water Supply, etc.—There are many odd jobs connected with the chemist's work in the textile industry which might be mentioned. There is the important question of fuel, and its efficient consumption. It is certain that the £8,200,000 returned as having been used by only a portion of the manufacturers engaged in this industry could be materially reduced. A reduction of only ten per cent. would mean a saving of £800,000. The often quoted case of a chemist who saved a large firm no less than £50,000 per annum in fuel alone will be remembered.

The nature of the water supply also plays an extraordinary part in dyeing operations. The importance of care in this direction will be realised when it is remembered that a large wool-washing establishment on the Continent has erected a plant to soften its water supply which, in its natural state, only shows 1 degree of hardness. In other cases a hard water may be essential, as in the weighting of black silk. Thus, in erecting new works, great attention must be paid to the possible requirements, and when more than one supply is available, the more suitable one must be selected. The purity of the steam supply, and also of any distilled water which may be used, must also receive attention.

Waste Liquors.—One of the most trying positions the chemist has to meet is connected with the disposal of waste liquors. These contain a variety of different substances, which in some cases will mutually precipitate one other, and the problem then resolves itself into one of "settling." Such conditions are, however, not always met with, and the difficulty is becoming one of increasing importance in view of the attitude of local authorities, and the, perhaps natural, demand for a return to the days when certain rivers and streams added beauty to the landscape. Certainly there is something very

distressing in the present aspect of some of these evil-looking streams of liquid, which must appeal to even the most hardened chemist.

The nature of the soap used, especially in the silk industry, often has an important bearing on results. Only certain kinds of soap can be utilised in some operations ; others are hopeless.

The humidity of the air may also be considered in certain works. Specially is this so in the working of cotton. A humid atmosphere is desirable, but may introduce all kinds of secondary difficulties by inducing bacterial changes and encouraging the growth of moulds.

The chemist will also be called upon to consider the question of efficient ventilation in the dye-house. The effect produced in some dye-houses, during the winter months, has to be seen to be believed. Drawing off air by a fan is worse than useless. Heated air is generally pumped in to prevent condensation.

The evidence that a merely chemical training is insufficient is fast accumulating, and may be emphasised. The chemist may, for weeks, be working in directions which are physical or even mechanical in their nature rather than chemical. The important point is that *his method of attack is based on a past training in chemistry* ; and that, because of this, it will be different from that adopted by the engineer. In this, its value rests. This is the point I have tried to emphasise in these lectures. Also that success in almost every case depends upon attention to detail. Thus, an inferior mind may sometimes succeed when once the main idea has been grasped. These are the two points I would bring to the notice of the young chemist who is entering the textile industry on the research side.

In the past, ideas have been circulated that work in this direction is of such a nature that the general chemical student should rather enter some other branch of industry : that, although the work involved is complicated, it is, in the majority

of cases, applied on so limited a scale, that the result is a comparatively insignificant one. This is incorrect. Many of the problems which have to be worked out are of great importance from an industrial point of view, and are connected with a large output of material. Investigation in this industry is exceedingly varied in its nature, and offers a wide field under modern conditions.

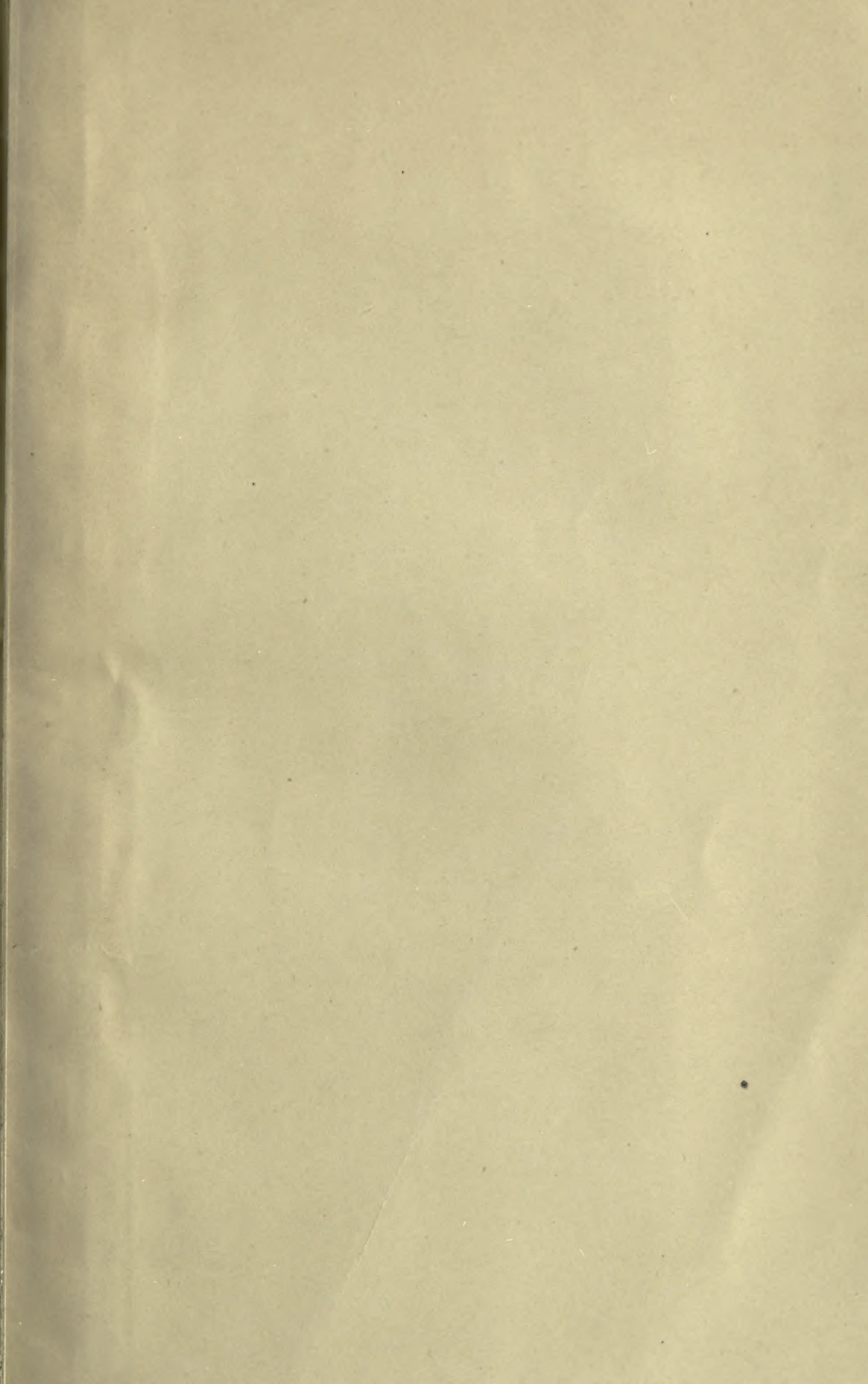
The need of the industry is undoubtedly the presence of a larger number of highly trained chemists. On the engineering side, this industry has never lacked good men, and their invention has led to a condition of supremacy of which we may well be proud.

From the textile chemist's point of view, the development of technical research may be said to have closely followed that of general scientific investigation. The establishment of numerous technical schools and colleges in this country during the last twenty years or so, has materially helped in this direction, although it must be acknowledged that, in many cases, some of these institutions in their youthful days have done remarkably little for the furtherance of research in its higher aspects as compared with the work achieved in the Continental schools. This is, however, a matter which is rapidly righting itself.

The formation of the Textile Institute has also achieved results by bringing to the notice of the technical colleges certain problems which demand serious attention.









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